ESSAYS

RESPECTING THE CHANGES WHICH THE

HUMAN SKELETON

UNDERGOES AT

DIFFERENT PERIODS OF LIFE;

AND THE DEFORMITIES TO WHICH IT IS SUBJECT DURING ITS DEVELOPMENT.

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ESSAY I.

WHEN we take a general view of the organization of animals, we remark great variety of structure. Every class possesses organs peculiar to itself; and the organs, which each class enjoys in common with others, are subjected to numerous modifications. Hence, those characters are very few, which are common to the different classes of animals, or to the same kind of organ in different animals. Their resemblance often consists in little more than in the effect produced. To ascertain these varieties and their laws, at the

most important of which we arrive by an analysis of the conditions of existence,* is the object of Comparative Anatomy: a science indispensable to General Physiology and Natural History.

If we confine our observations to the structure of the different varieties of the same species, or even to the organization of the same individual under different circumstances, we shall also observe the same kind of organs subjected to perpetual varieties; for,

1st. Every organic body is destined to undergo, during the progress of its natural existence, a series of changes more or less remarkable; losing certain parts, and developing others, which were either much less considerable, or did not exist. The metamorphose of the caterpillar into the butterfly, and of the tadpole into the frog, &c. are obvious and striking in the extreme; but the changes, which the higher or more complicated animals undergo, though not so remarkable, are nevertheless as real. The infant, at birth, loses its placenta and coverings; at a certain period, is nearly deprived of its thimus and renal capsules; and acquires, by degrees, its hair and its teeth. Moreover, the relative magnitude, and intimate structure of the different tissues and organs, undergo perpetual changes, from conception to the latest moment of a protracted existence; so that no being is possessed of an organization, exactly the same, at any two different periods of life.*

* " Comme rien ne peut exister s'il ne réunit les conditions, qui rendent son existence " possible, les différentes parties de chaque être doivent être coordonnées de manière à " rendre possible l'être total, non-seulement en lui-même, mais dans ses rapports avec " ceux qui l'entourent; et *l'analyse de ces conditions* conduit souvent à des lois générales " tout aussi démontrées que celles qui derivent du calcul, ou de l'expérience." Cuvier, Règne Animal distribué d'après son Organisation, Paris, 1817. Introduction, p. 6.

* Cuvier Règne Adimal.

2dly. Every organized body, on the surface of our globe, is subject to the powerful influence of physical agencies. We remark the same vegetable to vary in many of its most remarkable qualities, according to situation, &c. The tree of luxuriant branches and majestic grandeur, transplanted far from the genial influence of the solar rays, becomes a frail shrub, or even does not elevate itself higher than an herbaceous plant; and the savoury vegetable soon loses its qualities in a foreign land. If climate exercises such infinite power over vegetable life, to what extent, is it reasonable to suppose, can it influence the higher order of animals, connected as they are, so intimately, by one of their most important functions, with the atmosphere, in which they exist? If we cast our eye over the different species of Mammalia, we shall soon observe, that its influence on animals is fully as great, as we might, *a priori*, have been led to suspect, from observing its action on the vegetable world. In fact, we remark the same animal assuming different statures, new forms, various colours, and changing the proportions of its different parts, according to the circumstances, in which it is placed. Even man, who can, more than any other animal, accommodate himself, without undergoing very material changes, to all climates, all temperatures, the different varieties of atmosphere, and every mode of life, alters his organization to adapt himself to these various circumstances. He assumes a different stature, another colour of the skin, and undergoes alterations in his moral and intellectual character. The modifications, which the same species exhibits under different circumstances, produce what are called varieties; and these varieties are so remarkable, that we are often at a loss, whether to consider them as simple varieties, or as different species.

3dly. Obvious and remarkable characters distinguish the different sexes. We find peculiarities in each, not only in respect to those

organs and their functions, on which the sexual character depends, but also observe, that these peculiarities necessarily demand others, in almost all the component parts of the organization.

4thly. The different temperaments and idiosyncracies depend on peculiar modifications of structure; which, although scarcely sensible, must nevertheless exist. And,

5thly. The organs of every living body are subject to lusorial varieties; whether from defect or disease in the procreative functions of the parents, or from other and more concealed causes.*

Hence, the varieties afforded by the same kind of organs in different individuals of the same species, or in the same individual under different circumstances, are scarcely less remarkable than those, which are to be found between the same kind of organs in different classes; and a knowledge of these varieties would, perhaps, be equally pregnant with interest and utility. An inquiry, which would have for its object the varieties afforded by the organization of the human species, arising from the causes just mentioned, might, with great propriety, be denominated *Human Comparative Anatomy.*

Although Human Comparative Anatomy has not been entirely neglected, (for, since the middle of the last century, we find the most illustrious Anatomists† convinced of its importance, and much devoted to its advancement,) it is far from having created that general interest, and procured that share of attention, which its great importance demands. When it is considered, that the science of anatomy will ever be imperfect, until it has ascertained all the natural varieties of structure;—that the Anatomist can never hope to arrive at the

* Varieties of organization, the effect of diseased action of the individual, are not, of course, here taken into consideration.

† Haller, Albinus, Hunter, Bichat, Blomenbach, Soemering, Scarpa, Prochaska, Reil, Portal, and the Wenzels.

general laws of our organization, until his data are complete;—that, if the function is not solely the result of organization, it must be admitted there is an intimate connexion between the actions of the different organs and their structure; and hence, that every modification of texture is necessarily accompanied by corresponding modifications of function;—that a knowledge of every variety in organization is indispensible to the Physiologist and Pathologist, and consequently to the Physician and Surgeon, whose arts are founded on Physiology and Pathology; and that it affords to the naturalist the only rational basis, on which he can attempt to reason respecting the unity of the human species and its varieties;*—I say, when all this is considered, one is astonished to find, that, from the moment, when a tolerable knowledge of the anatomy of the adult was obtained, Human Comparative Anatomy did not become a grand object of investigation. Now, as it may be presumed, that every enquiry, *in any way tending* to promote the interests, and advance the knowledge, of a subject so interesting and useful, would be acceptable to the Academy, the author is induced to communicate to them the *results* of a great number of dissections, undertaken with the view of ascertaining the changes, which the human skeleton undergoes at different periods of life;† and, if they should be considered as calculated to assist in the ad-

* " L'étude de l'Anatomie, dans les divers âges de la vie, offre un nouveau champ de dé-
" couvertes; et il n'est pas douteux, qu' en la cultivant, on ne parvienne à concilier les
" opinions des divers anatomistes, parce qu'ils ont regardés comme constant, ce qu'ils n'ont vu
" que dans un seul âge de la vie."—*Portal, Mémoires de l' Academie des Sciences, ann.* 1771.

† It is not intended to investigate, at present, the changes which the *structure* of the bones undergoes at different periods of life. This will form the subject of a future enquiry: the present being limited to the consideration of the changes in the form, and relative proportion, of the whole skeleton and its different parts.

vancement of a science, perhaps of the first importance to mankind, he will, as soon as more pressing duties permit, communicate other facts, which he has collected respecting the development of other organs.

A division of the skeleton, founded on physiological principles, would, if attainable, be much superior to any other, in the consideration of the phenomena exhibited during its development; but such a division is impracticable, in consequence of the same part being frequently subservient to very different functions. We must therefore follow an arrangement founded on the portions of the body, into the formation of which the different parts of the skeleton enter; and as, perhaps, none will answer the object of this enquiry better, than the common division into head, trunk, and extremities, it will be followed throughout these Essays.

I. HEAD.

The head is composed of a great number of bones, so arranged and connected together as to form an assemblage of cavities, destined for the reception and defence of important parts; particularly the brain, and many of the organs of external sensation.* Each of these cavities may therefore form the head of

* The organs of sensation are divisible into external and internal. The former make us acquainted with surrounding bodies, and the latter with the state of our own system.

a section, in an enquiry into the development of this part of the skeleton; consequently the cranium, auditory cavities, orbits, mouth, and nasal fossæ, which afford lodgement to the brain, the organs of hearing, vision, tasting, and smelling; as also those parts of the bones of the head, which are subservient to the function of mastication; will successively come under our consideration; and will naturally lead to some observations, respecting the changes, which the head in general undergoes, in consequence of the changes of its particular parts.

SECTION I.

CRANIUM.

The proportion of the cranium to other parts of the skeleton, and of the several regions of the cranium to one another, at different periods of life, forms a curious and interesting object of inquiry. The rapidity of its growth, when compared with almost all the other cavities of the head, and with the entire skeleton, has, at all times, attracted considerable attention, and been a fruitful source of speculation; but the relations, that exist between the development of its different parts, have been, in a great measure, overlooked.

Between the third and fourth week after conception, the cranium is observed. It has then the appearance of a vesicle containing the infant brain; and forms, at least, one half of the whole embryo, and the entire of the head: for the other cavities cannot be distinguished. By degrees, the face is developed; but, for a long time,

we are astonished at the small proportion, which it bears to the cavity containing the brain. The predominance of the cranium, compared with the other cavities of the head, and with the entire skeleton, (though gradually diminishing, from almost the first moment of formation,) is preserved, to a certain extent, till the completion of growth. Not merely till the cranium has ceased to grow; but, till all the other parts of the skeleton have acquired their permanent dimensions.

From observations I have made, I am convinced, that the *cavity* of the cranium has arrived at its permanent dimensions, at the eighth year of our existence, or perhaps sooner. To general observers, this remark would not appear correct. Their attention is, however, only directed to the *exterior* of the cranium; and, it must be admitted, that, after this period, the cranium, viewed externally, increases in its dimensions; but this increase of external dimension has no influence on the cavity. It is produced by an increase of the thickness of the bones of the cranium and their coverings. This fact is confirmed by the observations of the Wenzels;* these accurate and indefatigable anatomists having observed, that the brain, which is contained in, and fills this cavity, has attained its permanent dimensions at the age of seven years. As therefore the cavity of the cranium has arrived at its maximum, between the seventh and eighth year, (a period much earlier than any other part of the skeleton,) it follows, that the permanent relations of magnitude are not established, when the cranium ceases to grow; but at the conclusion only of the development of the entire skeleton.

The cavity of the cranium does not increase, in the same ratio,

* Wenzel, (Joseph and Charles,) de Penitiori Structura Cerebri Hominis et Brutorum. Fol. Tubingen, 1812, p. 254, 295.

during all the periods of its growth. At birth, it has acquired much more than one half of its permanent dimensions; consequently it grows, during the nine months of uterogestation, more than from birth to the eighth year, when its development is complete. Indeed, it would even appear to increase, during the seven months previous to parturition, more than during as many years after birth.

The cranium is generally considered as containing a single organ. Now, as it may be supposed, that all parts of the same organ will grow in the same proportion, and, as there is a connexion between the development of the cranium and the parts it contains, we should be naturally led to expect, that all parts of this cavity would grow with equal rapidity. Observation, however, proves this supposition to be erroneous; and demonstrates, that, not only the various parts of the cranium develop themselves in different proportions, but also that each portion of the brain has a rapidity of growth peculiar to itself.

If a line be drawn round the cranium, passing over the nasal and external occipital protuberances, it will be separated into two portions, a superior and inferior. These two portions grow very unequally. The upper part, which is called the vault, is developed much more rapidly than the under, or base.

Let the vault of the cranium, in its longest diameter, be divided into five equal parts. The two anterior fifths grow less rapidly than the three posterior. Of the three posterior fifths, the two anterior are most rapid in growth. As, therefore, the vault of the cranium grows more rapidly than the base, and as that part of the vault, where the two posterior join the three anterior fifths, is, of all parts of the vault, the most rapid in its growth, it follows, that this por-

tion of the cranium holds a predominance over all the others, till their development is completed.

From measurements which I have made, it would appear, that the longitudinal, transverse, and vertical diameters, do not bear the same proportion to each other at all periods. The vertical diameter is proportionably smaller during early life; more particularly where it corresponds to the posterior fossa of the cranium, which lodges the cerebellum. This would appear to depend on the slow growth of the base. The transverse diameter proportionably exceeds the longitudinal, till the third month after conception: hence the spherical form of the head at this period. From the third until the ninth month, the longitudinal diameter grows more rapidly than the transverse, which causes the elongated form of the head at birth; and, from birth until the growth is completed, the proportion of the transverse to the longitudinal gradually increases, when their permanent relations of magnitude are established.

These observations appear, in some measure, to favor the doctrines of Gall and Spurzheim, respecting the functions of different portions of the brain: doctrines, which have excited much unmerited ridicule. Though their conclusions (many of which are supported by numerous facts,) have not hitherto received the sanction of general experience, to deride them, solely on that account, is highly absurd. Since it has pleased Providence to make an organized material substance the medium of all the mental faculties, it is not irrational to suppose, that these several faculties may depend, for their existence, on certain parts of the organized mass; and, for their degree, on the proportion of these parts.*

The irregularities for the attachment of muscles, observed in the

* See Parry, Elements of Pathology, London, 1815, vol. i. p. 281.

base of the scull, are not as large, in proportion to the size of the cranium, in early life, as afterwards; but there is, at all times, the same proportion between the magnitude of the foramina, for the transmission of nerves and blood vessels, and that of the cavity of the cranium: with this exception, however, that the hole, through which the blood of the lateral sinus passes, is relatively smaller in proportion to the youth of the subject.

There occurs, at different periods, a very remarkable change in the position of the large foramen of the occipital bone. The younger the subject, the nearer this foramen, and consequently the condyles, for the articulation of the occiput with the spine, to the centre of the base of the cranium. There is probably a connexion between the situation of this hole and the development of the face; for, the greater the development of the face, the farther the foramen is removed backwards; and it is likely, that its place in the adult is determined by the quantity of room required for the face and pharynx. Its situation however, in early life, so much nearer the centre of the base than afterwards, must be considered as, in some measure, owing to the greater rapidity of the growth of the posterior than anterior parts of the cranium. Whatever may be the cause, which determines this peculiarity, it serves the useful purpose of rendering the head more easily supported by the action of its muscles; which are, in early life, but weak, compared with the size of the cranium.

The varieties of structure, which the cranium exhibits, at different periods of life, will be more fully considered, when speaking of the changes of structure, which the whole skeleton undergoes; but, as some observations on this subject appear to be here required, I shall make a few remarks, reserving the remainder for a future occasion.

The walls of the cranium, when this portion of the skeleton

can be first distinguished, are composed solely of a semitransparent and very delicate membrane. By degrees its density and thickness encrease. It becomes firmer and more opaque ; and, about the middle of the second month after conception, it can with ease be shown to consist of two layers. From the manner, in which the bone is afterwards deposited, between the layers of this membrane, it may probably be considered as the rudiments of the dura mater and pericranium. These two membranes (for I shall now consider each layer as a distinct one,) are connected by the medium of a tissue, apparently cellular, and looser than the membranes themselves ; but this medium does not resemble, nor do they, at this period, contain between them any thing like cartilage. Their nature, and the resemblance between them and other structures, cannot, in consequence of their delicacy and imperfect organization, be determined ; but, as well from some observations on them at this period, as from their nature, when more fully developed, I suppose them to be of the same structure as that tissue, which Bichat calls fibrous.

About the end of the second month, the walls of the cranium undergo a remarkable change. Cartilage is deposited between the dura mater and pericranium in the base ; but not, as is supposed, in the vault.* The deposition of the cartilage in the base is even limited to particular parts. I have observed cartilage in the situation, where the æthmoid, the body of the sphenoid, the petrous portion and mastoid process of the temporal, and the lower part of the occipital bones, are developed ; but, not in the situation of the orbital processes of the frontal, or temporal wings of the sphenoidal.

* Kerkringius, Osteog. Fœt. cap. II.

The next change, observed in the structure of the cranium, is the deposition of bone. The period, at which this takes place, is rather indefinite. It always, however, commences some time in the course of the third month, and earlier in the base than in the vault. Bone will generally be found in the base, at the beginning of the third month; and, in the vault, towards the termination of the same month.

The deposition of bone, in the base, is made in the cartilage, which, as I have mentioned, previously existed there; but, in the vault, in the medium, which connects together the two membranes of the cranium: a medium, which I have already asserted, and which I shall hereafter prove, to have no resemblance to cartilage. There is, therefore, this remarkable difference between the structure of the base and vault, during their development, that, in the former, cartilage precedes the formation of bone, but not in the latter. These facts, with which Anatomists do not appear to be generally acquainted,* will, on a future occasion, obtain considerable attention. At present, I shall not take into consideration, either the causes of cartilage preceding bone in the base, or of its nonexistence in the vault, further than to observe, that both the existence of cartilage in the base, at a period, when the rest of the cranium is only membranous, and the commencement of the deposition of bone in the same situation, before it is observed in the vault, are arrangements, which appear to be necessary, for the purpose of affording, at as early a period as possible, defence to the base of the brain; which, it is well known, cannot bear mechanical injury with so much impunity as the vault.

The number of distinct points of ossification found in different

* See Nesbit's Osteogeny.

parts of the walls of the cranium, the rudiments of the future bones, is subject to some variety, owing to the occasional formation of those little bones called Wormian; but, I believe, with the exception of these, twenty-six will in general be found.*

These bony nuclei are necessarily, at first, separated from each other by a considerable interval; and are held in contact, in the base, by the cartilage which surrounds them, and by the membrane that lines their internal and covers their external surfaces; but, in the vault, merely by the membranes and medium, which connects these membranes. By degrees, the nuclei encrease, both in thickness and superficies, so as to diminish the interval, which at first existed between them. This increase is much more rapid in the base than in the vault. However, even here, and in those skulls which grow most rapidly, there are very few, if any, of the bony nuclei brought into contact before the sixth month after conception.

At birth, ossification is so far advanced, that almost all the bones in the base are in contact with each other; and any interval, that exists between them, is filled up by the cartilage surrounding their edges; but, in the vault, there are few places where the edges of the bones are contiguous; being, in almost every part, separated by an interval, in some situations of considerable extent, and connected by the dura mater and pericranium, which line their internal, and cover their external surface. There is also a very thin stratum of cellular substance,

* The frontal is formed by two, the occipital by four, the spheroidal by three, the æthmoidal by three, each temporal by three, each parietal by one, and each of the small bones of the ear generally by one.

which serves to connect these two membranes in the intervals of the bones, and also the bones themselves; for it passes from the edge of one bone to that of another. It is to be observed, that those bones, which form the posterior part of the vault, have extended their growth farther than those, which constitute the anterior part. Hence the smaller size of the occipital, when compared with the frontal fontanella: a fact observed by Morgagni,* and considered by him to depend on the cerebellum requiring to be well defended during parturition.

These facts, respecting the changes in structure, which the walls of the cranium undergo at different periods, prove, that the ossification of the base advances more rapidly than that of the vault. This does not, on a first view, seem to accord with the observations just made on the growth of the dimensions of these two parts of the cranium, compared with each other. It has been already remarked, that the base is much slower in developing itself than the vault; but this observation only related to the growth in dimensions, not in structure. It may, however, appear extraordinary, that there should not be a connexion between the growth of the structure, and the growth of the dimensions. The cause of this want of connexion is, however, on reflection, very evident. The development of the cranium in dimensions must keep pace with the development of the dimensions of the brain; but the growth in structure is connected with the necessity, which the different parts of the brain have for defence; therefore, as the dimensions of that part of the brain, which corresponds to the vault of the cranium, grows with greater rapidity, the same must occur with respect to the corres-

* Adversar: Anat. 11. Animad. 32.

ponding part of the cranium. On the other hand, the base of the brain, where the origin of all the nerves is situated, requires more secure means of defence; hence the corresponding part of the cranium has its structure, on which its powers of defence depend, rapidly developed.

In the cranium of a fœtus at birth, we remark two beautiful arrangements, destined, at the same time, to facilitate the process of parturition, and to protect that part of the brain, which more particularly requires defence. Ossification has, at this period, as I have already remarked, so far advanced in the base, that almost all the bones are contiguous ; and, where there is any interval between their edges, it is filled by a cartilage having considerable powers of resistence. At the same period, the bones of the vault are separated, to a considerable extent, from each other, and only united by membranes. This conformation gives to the base a great degree of strength, and enables it to resist any pressure, which would be likely to alter its form, and thereby injure a portion of the brain, very sensible to every mechanical violence ; while the bones of the vault are enabled to approximate, and even to overlap each other ; a change, which, in consequence of the structure of this part of the brain, can take place with impunity. From all these considerations it appears, that it is by alterations in the form of the vault, and more particularly of its anterior part, that the head accommodates itself to the form of the pelvis during parturition.

After birth, the bones extend themselves to such a degree, as, not only to increase the dimensions of the cranium, but also to approach each other ; and thereby diminish or annihilate the intervals, which separated them in earlier life. At last they have arrived at such a state, that they are almost every where in contact ; and we remark, that their edges have then assumed forms of va-

rious kinds, preparatory to their union with each other. Those bones, which are in the base, have plane edges;* those on the sides of the vault are so constructed, that one bone shall overlap the other;† those on the top of the vault are serrated, by which they are mutually enabled to receive and support one another.‡ It will be admitted, that the cause of all these peculiarities has never been satisfactorily explained. Some Physiologists, unable to conceive the possibility of any occurrence in the body, without a mechanical cause, have attempted to account for the phenomena on mechanical principles. By them we are told, that the bones of the cranium overlap each other at the side, in consequence of the pressure of the temporal muscle;§ and that the conformation of their edges in the top of the vault, where they are serrated, arises from the bones ossifying in the form of radii, and hence mutually receiving each other, when they meet.¶ Their opinion is, however, proved to be without foundation, when it is considered,

First, that the overlapping of the bones of the cranium is to be observed, where neither the pressure of the temporal muscle, nor any mechanical agency, with which we are acquainted, can exist·

* Harmonia. † Sutura squamosa. ‡ Sutura vera.

§ The manner how I imagine this sort of suture is formed at these places is, that, by the action of the strong temporal muscles on one side, and by the pressure of the brain on the other, the bones are made so thin, that they have not large enough surfaces opposed to each other to stop the extention of their fibres in length, and thus to cause the common serrated appearance of sutures, but the narrow edge of one bone slides over the other. Monro's Works, edited by his Son, p. 75.

¶ "The *suture* is that articulation, where two bones are mutually indented into each other, or as if they were sewed together; and is formed by the fibres of two bones meeting, while they are yet flexible and yielding, and have not come to their full extent of growth: so that they mutually force into the interstices of each other." Monro's Works, edited by his Son, p. 55—56.

Hence, it may be presumed, that, as the cause, which produces the overlapping in one situation, produces it in others; and, as this cause is certainly in many situations not mechanical, it may be inferred, that it is not mechanical in any.

Secondly. If the serrated appearance of the true suture was caused by the accidental union of the ossifying radii, it should be found, in all situations, where the radii exist at the commencement of ossification; and, as the appearance of the radii is, in all situations, the same, the serrated suture should, every where, have the same form. Neither of these, however, is the case.

Thirdly. Neither mechanical pressure, nor the pre-existence of radii, would explain the cause of the form observable in the edges of the bones in other situations; in the base, for example, where they meet by plane surfaces.

Fourthly. There is no reason to suppose, that the cause of the conformation of the articulating surfaces of the bones of the cranium is different from that, which determines the form of the articulations in other parts of our skeleton; and, as it is universally admitted, that these depend on the laws of our organization, and not on any accidental mode of ossification, or on mechanical pressure, it is much to be wondered, that physiologists should have, for so long a time, attributed the nature of the articulations of the cranium to such causes.

Finally. The admirable adaptation of the edges to their uses, which, I shall just now prove, must immediately force us to conclude, that their construction depends on some immoveable law of nutrition; and not on the uncertain influence of mechanical pressure, or the accidental formation of radii.

I shall not now take into consideration the advantages arising from the cranium being composed of a great number of bones.

For the present, however, it may be admitted, that this conformation was necessary; and hence it became indispensable, that the several bones should be united in such a way as to remove, as much as possible, every kind of inconvenience likely to arise from such organization. This appears to be the principle, which regulates the form of the edges of the bones. How well the articulations of the cranium are calculated to answer this end will appear from a consideration of the mechanism of this cavity in resisting injury.

If any pressure be made on the anterior, posterior, or lateral part of the cranium, so as to act directly on the base, it resists in consequence of the mutual support, which the bones afford each other, by means of the broad and plane surfaces, with which they are united. This mode of articulation is, therefore, peculiarly well adapted to the base; for, if the bones were here united in such a manner as either to overlap, or with narrow edges mutually to receive each other, they would not be able to oppose the necessary resistance.

If the top of the vault be pressed on by the fall of a heavy body, by the weight of a load placed on the head and acting perpendicularly, or by any broad and resisting body impelled against it, the motion is divided and propagated in all directions. The portion of the impulse, which acts perpendicularly, tends to drive in the part pressed on; but this is effectually prevented by the serrated form of the articulations of the bones in this part, by means of which they are enabled mutually to receive and *support each other:* and that portion which acts laterally, tends to drive outwards the lower part of the parietal bones; but, as they are overlapped by the sphenoid and temporal bones, which form to them a kind of buttress, this cannot take place, unless these bones perform a revolutionary

motion. This, however, is effectually prevented by the breadth of the plane surfaces, by which the bones in the base are united.

As these few observations are sufficient to illustrate the function of each kind of articulation, I shall not farther enlarge on the subject. It may, however, be here remarked, that the respective functions of each kind of articulation is so accurately fixed, that the nature of the injury, to which particular parts of the cranium are subject being known, we could, *a priori*, determine the kind of suture to be found in each part. These observations will perhaps be considered as of some importance, in consequence of their affording principles, by which we can explain the causes of the innumerable and hitherto apparently capricious varieties remarked in the articulations of the cranium. They also demonstrate the connexion, which exists between their construction and the well being of a cavity destined to protect the most important and most delicate organ of our system; and we are thereby forced to consider their formation as depending on determined laws, and not on the uncertain influence of pressure, or the accidental formation of radii.

Anatomists not fully acquainted with the manner, in which the true suture enables the bones that form it, mutually to support each other, have been much at a loss to explain a peculiar appearance, exhibited by this kind of articulation: the existence of serræ only on the external surface of the cranium. The common mechanical explanation being not only entirely inadequate, but almost, if not wholly, unintelligible.*

* It must be observed, that the indentations of the sutures do not appear on the inside of the cranium by much so strong as on the outside; but the bones seem almost joined in a straight line: nay, in some skulls, the internal surface is found entire, while the sutures are manifest without, *which may probably be owing to the less extent of the concave than of the convex surface of the cranium, whereby the fibres of the internal side would be stretched farther out at the*

If we consider the function of this suture, which is to enable the bones, that form it, mutually to receive and support each other; and the manner, in which the conformation of their edges perform this office, the appearance is easily explained. The bones of the cranium are composed of two layers or tables, an external and an internal. In the serrated suture, the external table of each bone is applied on the internal of the other, in such a way, that the latter supports the former. It is therefore necessary, that the external table of both bones be *mutually* prolonged over the internal, upon which they lie, and from which they receive their support. This is accomplished in the following manner. A number of serræ or processes belonging to the external table of one bone, for example, of the right parietal, pass into cavities or fissures for their reception, in the external table, and on the internal table of the opposite bone, or left parietal; while, in return, an equally great number of serræ of the left parietal pass into cavities for their reception in the external table and on the internal table of the right parietal. It is easy to apply these observations to explain the cause of the existence of the serræ externally, and consequently of their absence internally. Thus, we have seen, that, in this kind of articulation, the internal tables support the external. Now it is necessary, first, that the external table shall be prolonged over the internal, from which it receives support; secondly, that the external

edges of the bones than the exterior ones, if they were not resisted. The resistences are the fibres of the opposite bone, the parts within the skull, and the Diploe; of which the last being the weakest, the most advanced fibres, or serræ, run into it, and leave the contiguous edges equal, and more ready to unite: whereas the serræ of the external table have space enough for their admission between the fibres of the opposite bone; and, therefore, remain in the indented form, and are less liable to the concretion whereby the sutures are obliterated. Monro's Works, edited by his son, p. 76. See also Hunauld, Mem. de l'Acad. des Sciences, 1730.

tables shall be serrated, that they may *mutually* receive each other, and thereby allow the external table of each to be *reciprocally* supported by the internal table of the other. If the external table was not prolonged over the internal, there could not be any support given; and, if there was not an interlacing of the external tables, there would not be a *mutual* support. As the circumstances, by which each of the tables is affected, are different, the serrated conformation, necessary in the external table, does not exist in the internal; for no advantage could be derived from their interlacing, but a great inconvenience would result from it, as the internal table would be thus rendered nearly unable to support the external.

These considerations prove, not only the mechanism of the kind of articulation, which exists in the vault, but also how admirably it is calculated to answer the desired end. Had the bones been here connected by plane surfaces, as they are in the base, they could not afford any support to each other; or had *one* bone overlapped the other, one only would be supported, and the other easily driven in.*

While the bones of the cranium are separated, by a considerable interval from each other, I have already remarked, that they are retained together, in the vault, partly by the dura mater and pericranium, and partly by a very thin stratum of cellular substance, which passes from the edge of one bone to the edge of another; but, in the base, by a cartilagenous substance, which surrounds the edge of the growing bone, and by the membranes covering the cranium, and lining its internal surface. Such is, for example, the state of the cranium at birth. In proportion as the bones are increased, this interval between them is diminished, and the medium of connexion modified in its nature. In the cranium of a child, about twelve months old, we remark, that the very thin stratum of cellular substance, which

* See Winslow, Mem. de l'Acad. des Sciences, 1720.

formed, at an earlier period, the medium of connexion between the edges of the bones in the vault, is converted into a membrane much thicker, more unyielding, of a fibrous structure, and resembling more nearly the texture of a very strong fibrous membrane, than any other tissue in the body. At the same period, the cartilage, which joined the bones in the base, is less in quantity, the bones being now more closely applied to each other; and it has assumed the appearance of fibro-cartilage. If the cranium be examined, when its development is a little farther advanced, the edges of the bones are so closely applied to each other, that no medium of connexion is observable; hence the cause of anatomists remaining so long ignorant of the existence of an animal substance, between the edges of the bones of the cranium, when their articulations are perfectly formed.* From observing the state of these articulations at the earlier periods of life, I was led to suspect, that, even when they are most perfect, there exists between the bones, that form them, an animal substance; and I was able, by the following simple process, to demonstrate, not only its existence, but also its nature. I deprived a recent cranium of its soft coverings, and subjected it to the action of dilute muriatic acid, with the intention of examing the nature of this medium; which I expected to be able to do, by depriving the bones of their calcareous matter. The cranium had not been long exposed to the acid, when it was rendered flexible, and appeared formed of one continuous sheet of cartilage. The cartilagenous basis of all the bones of this cavity is therefore continuous, there being no interruption, as is generally supposed, where these bones are articulated together. Thus we observe, that, when the articulations of the bones of the cranium are perfectly formed, there is a cartilaginous medium of union, which serves to keep the bones, which form the cavity, in contact; and this cartilaginous medium is, at this period, continuous and of

* Bichat, Anatomie descriptive.

the same nature with that, which constitutes the animal basis of the bones themselves.

Towards the latter periods of life, the quantity of cartilage between the edges of the bones is gradually diminished by the progress of ossification; and the osseous substance of one bone, at last, becomes continuous with that of those, with which it is articulated. By this means all appearance of the articulations is removed, first on the internal surface, and afterwards on the external; and, if death did not put a stop to the progress of ossification, it would only terminate, when it had formed the whole cranium into one bone.

For a considerable period after birth, the bones of the cranium are very thin, and their structure uniform. By degrees their thickness increases, and their surfaces becoming very compact, while the interior assumes a cellular appearance, what are called the tables and diploe of these bones are formed; but, in very advanced life, the texture of these bones becomes uniformly compact, and the cellular tissue is obliterated. Hence the existence of tables and diploe is peculiar to the middle period of life, and are not be found well marked either in the very young or very aged subject.

Read Feb. 22, 1819.

SECTION II.

AUDITORY CAVITIES,

Read, June 28, 1819.

THE auditory apparatus consists, 1st, of an assemblage of organs, which serve, by their physical properties, to collect, transmit, and modify, the immediate cause of the sense of hearing.—2dly, of a nerve destined to receive and convey to the brain the impressions of sound. The cavities in the temporal bone, which are subservient to these parts, may be called auditory; and are naturally divisible, according as they belong to the former or the latter, into the tympanum, with its appendages, and the labyrinth.

The tympanum and its appendages offer to our consideration a great number of parts, whose development must be separately considered. On the external side of this cavity, we observe the external auditory tube and the groove, in which the circumference of the membrane of the tympanum is lodged; on the internal, the oval hole, the round hole, the promontory, and the pyramid;—anteriorly, the canal which lodges the internal muscle of the malleus, the eustachian tube, and the partition which separates them;—posteriorly, the mastoid cells and their opening;—superiorly and inferiorly, a number of little sinuses, or caverns, bony fibres, &c.—and, finally, in the interior

or middle, the cavity of the tympanum properly so called, and its bones.

At the termination of the *third month* after conception, we can first remark the rudiments of the external auditory tube. Two thirds of the circle of its root are, at this period, formed by a small bone, not thicker than a hair, curved, so as to describe a semicircle; and the remainder, by the roots of the mastoid and zygomatic processes. Its greater edge is convex, but the smaller is grooved, for the reception of the circumference of the membrane of the tympanum. Its thickness increases, and it gradually forms a larger portion of a circle; at first connected by a membrane to the parts, on which it lies. About the *fifth month* after conception, its bony union commences at its extremities; and, soon after, throughout its entire extent. Bone is now gradually deposited, along its concave or lesser edge; in such a way as to form the nonarticular part of the glenoid cavity, and afterwards the auditory process. In this manner, the lower and anterior part of the auditory tube is completed; and, by the gradual development of the zygomatic and mastoid processes, the upper and back parts are formed.

The diameter of the bony circle, which I have described as constituting the root of the auditory tube, is equal to the diameter of the tube itself, at any period of life; hence, it is only in length, that this tube encreases after birth. The period, at which the auditory tube gains its ultimate length, varies considerably; but, I believe, it will generally be found, about the 14th year, as long as at any after period; unless we except the portion, which is formed by the root of the mastoid process, and this is not perfected so soon.

I have been induced, from observing a close connexion between the growth of this tube and the organs of mastication, to consider the bony ring, first formed, in which the groove for the membrane of the

tympanum is placed, as the only part of the external auditory tube, directly subservient to the function of hearing, and that the rest is merely to protect the auditory canal from the pressure of the condyle of the lower jaw; which, was it not defended by the bony sheath, would be in constant danger of being compressed, and its area obliterated, whenever the inferior maxillary bone was extensively moved. In the earlier periods of life, when the condyles have not the power of extensive motion, the auditory tube does not exist; its place being occupied by a fibrous membrane, which is attached, by one end, to the edge of the curved bone that forms the rudiments of the auditory tube, and by the other, to the cartilaginous portion of the auditory canal.*

The groove of the auditory tube, in which the circumference of the membrane of the tympanum is encased, and which consequently regulates the line of direction of this membrane, is, when first observed, nearly horizontal. By degrees, it becomes so inclined from without, downwards and inwards, that at birth it is very oblique. Hence, as Bichat has observed, the membrane of the tympanum is, at that period, continuous and almost parallel to the superior side of the auditory canal; while the inferior side forms, with the membrane of the tympanum, a very acute angle, corresponding to the extremity of the canal. After birth, the direction of the groove becomes more vertical, and this alteration is accompanied by a corresponding one in the membrane of the tympanum. It may be here observed, that, as the diameter of the groove, in which the membrane of the tympanum is encased, is at birth nearly as large as it will ever be, so is the membrane itself.

* I here, for the sake of description, confine the term *auditory canal* to the tube, which conveys the air to the membrane of the tympanum; and wish to designate, by the words *auditory tube*, the portion of bone which enters into the formation of the auditory canal.

Two months after conception, the oval hole, which forms the communication between the vestibule or middle cavity of the labyrinth, and the tympanum, is, although very small, to be observed. About the end of the third month, its circumference is ossified. In the sixth month, it is as long and as perfect as at the ninth; but not so broad. I have not been able to remark any difference between the form and size of the oval hole of the fœtus at birth, and of the adult. But its position varies; for, in the fœtus, it is comparatively nearer the posterior side of the cavity of the tympanum than in the adult.

The round hole, the medium of communication between the cochlea or anterior portion of the labyrinth and the tympanum, is visible at the same time as the oval hole. About the third month, its circumference is ossified; and, in the course of the sixth month, it is as large as in the ninth, when it is equal in dimensions to what it will be in the adult, but of a different form; for in the adult it is rounded, but in the fœtus it is triangular.

We find, that the direction of the round hole is subject to great variety; and Scarpa,* who has paid very minute attention to its disposition in different subjects, is of opinion, that he has traced a connexion between its direction and the age of the individual. He says that, for some months after conception, this opening is directed rather anteriorly; that, at a more advanced period of uterogestation, it is successively turned downwards and backwards; that, at birth, its aspect is nearly directly backwards; and that it inclines itself more and more in that direction till a certain period, when its aspect changes, and is turned more outwards, so as to look towards the membrane of the tympanum. These changes in direction are attributed to the influence of the promontory and mastoid process. Before

* Anatomicæ Disquisitiones de Audito et Olfactu. Auctore, A. Scarpa.

the promontary is developed, the round hole is directed outwards; but, in proportion as its growth advances, it conceals this hole and directs it backwards. When the mastoid process develops itself, it occasions a new direction in the hole, which it turns again more outwards.

My observations on this subject agree with those of the illustrious Scarpa, so far as relates to the varieties, which we find in the direction of this hole in different individuals; but, I am fully of opinion, with Bichat and Buisson, that it is very difficult to trace any connexion between its aspect and the age of the subject. I have indeed, in my collection, preparations, which prove, that, in almost any two subjects of similar age, the aspect will not be found the same. While, in some cases, we shall find it possessed of the same direction, in preparations taken from subjects of very dissimilar ages, it will exhibit, in others, a different aspect, although they be of the same age. Whether the direction of this hole depends on the development of the promontory and mastoid proces is not easy to determine; but, if it is they which influence it, we ought to be prepared to expect much diversity; for the exact manner, in which they grow, is subject to considerable variety.

The promontory is visible about the third month after conception, and, in the fourth, it is ossified. It does not grow so quickly as the oval and round holes, which are above and below it; hence it has not attained its full size, till some time after birth; but it is developed with more rapidity than the cavity of the tympanum, into which it projects; and, therefore, about the fourth month after conception, it is in contact with the membrane of the tympanum. When we compare the promontory of a fœtus, at the ninth month, with the same part in the adult, they appear to differ, not so much in magnitude as structure. In the fœtus, it is porous and spongy; ut,

in the adult, extremely hard and compact. In the fourth month after conception, the pyramid is visible; and, about the fifth, the canal, which lodges the muscle of the stapes, is ossified. This canal is, in the fœtus, comparatively much nearer the stapes, than in the adult.

Until the middle of the fourth month after conception, neither the eustachean tube, nor the canal for the reception of the internal muscle of the malleus, are to be observed. The bony circle, which forms the rudiment of the auditory tube, crosses the place, where they are to be developed; and their first appearance corresponds with the period, when the circle is united by bone to the parts on which it lies. About the end of the fifth month after conception, their ossification commences. At first, there is no partition between these canals; but ossification, when it has begun, advances so rapidly, that they are almost fully formed at birth.

About the fourth month after conception we remark, at the upper and back part of the cavity of the tympanum, an opening of considerable size; which, in the fœtus at birth, leads into a cavity, found between the lower part of the squamous portion of the temporal bone, and the upper part of the petrous portion. This hole and cavity lodge the short leg of the incus, and are the rudiments of the mastoid cells, and their opening into the cavity of the tympanum. One cannot say that, at birth, there are any of the mastoid cells formed. This opening, which I have mentioned as seated at the upper and back part of the cavity of the tympanum, is of considerable size, and leads into a deep and wide fossa; but this fossa is not divided, as it will be in the adults, into a number of cells by bony partitions; nor does it lead downwards into any cells in the situation, in which the mastoid process is afterwards to be developed. The mastoid cells are to be considered as very slow in growth,

when compared with the other parts which we have examined; and they seldom acquire their ultimate magnitude till after the adult period of our life.

About the seventh month, the caverns and bony fibres, which exist in the upper and under part of the cavity of the tympanum, begin to be developed. They have, however, a different appearance now from what they exhibit in the adult; resembling, at this period, rather the cellular structure of the cancellated tissue of bones, than any thing else. It is not till a considerable time after birth, that they assume the same appearance which they present in the after periods of life. The bony fibres, which cross the bottom of the tympanum, have a regularly arranged appearance in adults, which is wanting in earlier life.

The cavity of the tympanum, two months after conception, is scarcely to be observed. The membrane of the tympany lies then in contact with the internal side of the cavity. In the third month it is more obvious; and in the fourth has attained a considerable extent at its upper part, where the opening of the future mastoid cells is observed. We remark a very considerable difference between the rapidity of the growth of the upper and under part of this cavity. The upper portion grows so much more rapidly than the under, that, although the former has, at the fourth month, a very considerable size, the latter, until the fifth, is scarcely observable. The slow growth of the lower portion would appear to be connected with the development of the eustachean tube; for it does not commence till the growth of the tube commences; and, like it, grows then so rapidly, that, at birth, it has acquired almost its permanent dimensions. It is also the slow growth of the lower part of the tympanum, which causes the horizontal direction of its membrane during the earlier months of uterogestation; and it is its gradual development

afterwards, by pressing outwards the lower part of the bony circle, that incases this membrane, which produces its oblique direction observable at birth.

I have not been able to observe the rudiments of the bones of the tympanum, before the beginning of the third month after conception. They are then in a cartilaginous state, and it is not till the termination of this month, that their conversion into bone commences; but their ossification then advances so very rapidly, that, about the end of the sixth month after conception, they have attained their permanent dimensions, and only differ from the same bones in the adult, in being a little less compact in their texture.

As these bones grow so much more rapidly than the cavity of the tympanum, in which they are contained, until the sixth month after conception, they appear to be closely enveloped by its lining membrane, and are almost every where in contact with its parietes; but, after this period, the capacity of the cavity, compared with the magnitude of the bones, becomes greater, and they are gradually removed to a distance from its sides.

There is a remarkable change observed to take place in respect to the direction of the long leg of the incus and its relations to the handle of the malleus, destined to enable these bones, which do not increase in magnitude after the sixth month, to accommodate themselves to the progressive development of the cavity of the tympanum. Until the termination of the fourth month after conception, the long leg of the iucus, and the handle of the malleus are parallel and in contact. After this period, the long leg of the incus is gradualllly removed from the handle of the malleus; and that extremity of it, which is connected with the orbicularis, directed inwards; so that they form, when the cavity of the tympanum is fully developed, a considerable angle with each other. By this change

the length of the chain of bones is accommodated to the increasing breadth of the cavity of the tympanum without undergoing any alteration in their magnitude.

The labyrinth, or second division of the auditory cavities, consists of the cochlea, vestibule, and semicircular canals. The tube, which conducts the auditory nerve to the labyrinth, may also be here considered.

About the second month after conception, we can observe the rudiments of the cochlea, vestibule, semicircular canals, and internal auditory tube, excavated in cartilage, though they are all remarkably small; but, before the conclusion of the third month, their dimensions are considerable, and their form well defined. In the course of the fourth month, ossification commences, generally, first in the cochlea, and afterwards, successively in the vestibule, internal auditory tube, and semicircular canals; those parts which are nearer to the point of the petrous portion of the bone ossifying sooner than those near the base. About the termination of the sixth month, all the cavities of the labyrinth are formed of bone; except a small portion of the semicircular canals, corresponding to the base of the petrous portion of the temporal bone. At birth their ossification is complete, and they all appear to be then as large as at any future period of life.

The substance of the petrous portion of the temporal bone, which encases and surrounds these several cavities, does not grow so rapidly as the cavities themselves; hence it exhibits several peculiarities in form, prior to birth, and for some years afterwards. During

the entire fœtal life, but the nearer conception the more remarkable, the petrous portion is marked by numerous eminences and excavations; owing to the labyrinth not being then so much covered by bone as to hide its inequalities. The point of the petrous portion of the bone, not prolonged beyond the cochlea, is, at this period, as it were, truncated and rounded. Of the excavations to be observed, the most remarkable is one situated under the superior semicircular canal, and particularly noticed by Nesbit and Bichat. It is also, in consequence of the small quantity of ossific matter covering the labyrinth, that the internal auditory tube, although as wide at birth as at any after period of life, is not as deep as it will be in the adult.

For a long time, there is a very striking difference between the structure of the bone, which forms the parietes of the cavities of the labyrinth, and that which covers them; the former being, almost from the moment of its first formation, extremely compact; while the latter, till nearly the ninth month, is very soft, spongy, and vascular; affording us an opportunity of examining with facility the anatomy of the labyrinth, in consequence of the readiness with which the spongy covering can be removed from the compact tissue which forms its walls.

In examining the development of the auditory cavities, our attention is strongly roused by the want of connexion observed in the growth of the different parts, which constitute them. The development of many portions is so extremely rapid, that, at the ninth month after conception, they have those dimensions which they are to enjoy

during the whole course of our existence;* while others are as remarkable for their tardiness of growth as these are for their rapidity.† In the present state of our knowledge of the physiology of these organs, I am afraid we cannot offer any satisfactory explanation of the final cause of this phenomenon. As, however, a knowledge of the changes, which an organ undergoes at different periods of life, constitutes an important portion of that series of data required, before we can hope to form any rational theory of the manner in which it performs its functions, we should collect industriously, and note with accuracy, every fact connected with the development of these cavities, although we may not be able, at present, to apply them to any very useful purpose.

* Viz. Cavity of the tympanum, groove for the membrane of the tympanum, bones of the tympanum, Eustachean tube, oval hole, round hole, promontory, pyramid, cochlea, vestibule, semicircular canals, internal auditory tube.

† External auditory tube, mastoid cells.